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GB A 2012659 GB 1259105 GB 1066806
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(54) Internally heated extruder screw for thermoplastic extrusion process

(57) In a single-screw extruder, a zone of the extruder screw ranging in axial length from 2 to 90% and preferably 2 to 50% of the flighted length is heated. The heated length comprises at least a portion of the melting zone 9 the screw, preferably at least 2% of the total length of the melting zone, and preferably extends from a point just beyond the commencement of melting, to a point at which the melting is no more than 75% complete.

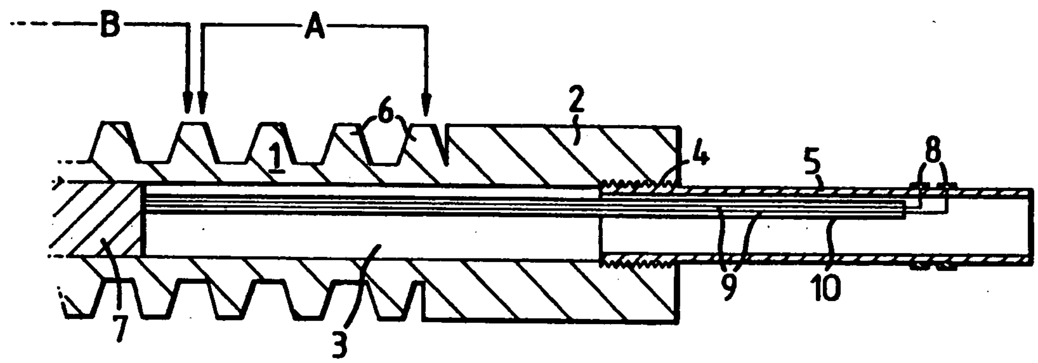

FIG.1

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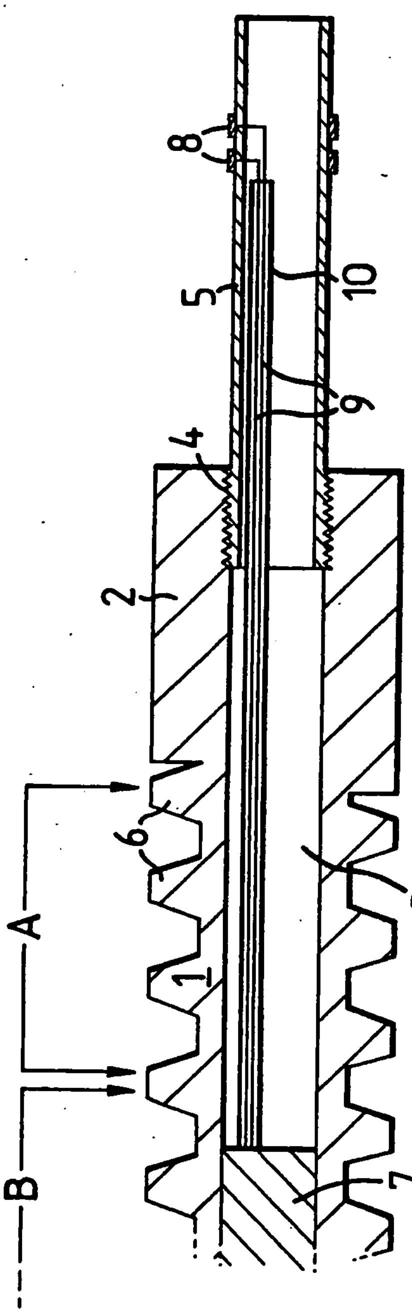

FIG.1

SPECIFICATION

Thermoplastic extrusion process and extruder therefor

The present invention relates to a process for the screw-extrusion of thermoplastic polymeric materials and to an extruder for use therein. More particularly the invention relates to extrusion using a single-screw extruder.

The use of single screw extruders to extrude thermoplastics materials, for example polyethylene, polystyrene and polyvinyl chloride is well known in the art. The function of the extruder is to melt and homogenise the thermoplastic material and to deliver it under pressure at a uniform rate to a die for shaping the thermoplastic melt to the desired form. Essentially, the extrusion process in a single-screw extruder comprises feeding powder, granules or pellets of the thermoplastic material into the channel of a helical screw rotating within the hardened liner of a heated cylindrical barrel. The screw is driven by an electric motor through a gear reducer and is prevented from rearward motion relative to the barrel by a thrust bearing. The thermoplastic material is conveyed forwardly along the barrel by the rotating screw and undergoes melting and homogenisation under the action of the external heat applied to the barrel and the internal heat generated by mechanical working of the melt in the screw channel. The extruder head and/or the die to which it is connected provide a restricted opening through which the melt can flow and considerable pressure is developed in the melt at the extruder head under the continuous "pumping" action of the rotating screw.

The output of an extruder in terms of the weight of polymer which can be extruded into useful articles in unit time is governed by a variety of factors including, inter alia, the geometry of the screw and barrel, the rate of rotation of the screw, the nature of the thermoplastic material, the dimensions and geometry of the outlet and die and the requirement to maintain an adequate pressure of thermoplastic melt at the extruder head (the "head pressure").

Such factors are of fundamental importance in the design and operation of extruders and dies and in the selection of appropriate grades of thermoplastic materials for manufacturing thermoplastic articles. It is both economically and technically desirable that in any extrusion process the extruder operating conditions can be controlled to optimise the output of extruded thermoplastics and/or to reduce the overall energy consumption of the process.

It is an object of the present invention to provide an improved process for extruding thermoplastic polymeric materials using a single-screw extruder. It is a further object of the present invention to provide an extrusion process having improved control over the operating conditions.

Accordingly the present invention provides a process comprising extruding thermoplastic polymeric material using a single-screw extruder characterised in that a zone of the extruder screw comprising at least a portion of the screw wherein the thermoplasic polymeric material undergoes melting is internally heated, the axial length of the internally heated zone being from 2% to 90%, preferably from 2 to 50% of the flighted length of the screw.

The present invention further provides a single-screw extruder for extruding thermoplastic polymeric material characterised in that means are provided for internally heating a zone of the extruder screw comprising at least a portion of the melting zone of the screw, the axial length of the internally heated zone being from 2% to 90%, preferably from 2 to 50% of the flighted length of the screw.

The single-screw extruder employed in the process of the present invention is preferably fitted with conventional barrel heating in addition to the internal heating in the screw.

The extruder screw can be of any design which is suitable for the extrusion of thermoplastics materials. Conventional extruder screws generally possess zones which are specifically designed to achieve one or more specific functions. For example the section extending from beneath the feed hopper up to the section where melting commences is frequently referred to as the "feed" zone or "solids conveying" zone. Similarly, there are frequently sections of the screw designed to compress the melt, to mix the melt or to meter the melt; these are referred to, respectively, as the "compression zone", the "mixing zone" and the "metering zone". In some extruder screws there may be for example relatively sharp transitions between the various zones which may take the form of rapid changes in the depth of the screw channel or in the pitch of the screw whilst in other screws such transitions, if any, may take place more or less gradually over substantial portions of the length of the screw. In a typical extruder screw used for the extrusion of thermoplatics, the feed zone is generally provided with a deeper channel and/or a wider screw pitch than is present in the metering zone and the change in channel depth and/or pitch may for example take place gradually over the whole length of the screw, or less gradually in a definable transition zone.

In the process of the present invention it is preferred to employ an extruder screw having a deeper channel and/or wider pitch in the feed zone. For further details of extruder screw designs suitable for use in the present invention reference may be made to the patent and other technical literature available which will be well known to those skilled in the art, for example,

"Processing of Thermoplastic material" edited by E.C. Bernhardt published by Van Nostrand Reinhold Company, and "Extrusion of Plastics", Edited by E G Fisher and published in London by Iliffe and Sons Limited.

The internal heating means of the extruder screw is suitably situated within the core of the screw. The heating means is adapted to internally heat at least a portion of the screw wherein the thermoplastic polymeric material undergoes melting, i.e. to heat at least a portion of the "melting zone". The "melting zone" is herein defined as meaning the section of the screw from the commencement to the substantial completion of the melting of the thermoplastic polymeric material. Suitably the internal heating means extends along at least 2 length %, preferably at least 5 length %, most preferably at least 10 length % of the total length of the melting zone. It is preferred that the internal heating should not extend into the region of the screw where melting is complete to avoid undesirably raising the temperature of the melt. In a particularly preferred embodiment of the process of the present invention, the internal heating means extends from the point where melting commences, or from a point within the melting zone just beyond the commencement of melting, to a point within said melting zone at which melting is no more than 75% complete, preferably to a point at which melting is 25 to 50% complete.

The internal heating means employed in the process of the present invention may comprise, for example, electric resistance heating, electric induction heating or the use of heated fluids, for example hot oil or superheated steam. In the case of electric heating, the electric power can be fed to the heater 'element', for example, through insulated conductors within the core of the screw via slip rings or a commutator situated on any convenient exposed portion of the screw shaft or on an axial extension thereof.

In the case of fluid heating, the hot fluid can, for example, be circulated through insulated ducting within the core of the screw to a heat exchanger or merely to a cavity within the defined portion of the screw where the heating is required. The hot fluid can be fed to and removed from the ducting, for example, using rotary valve connections situated circumferentially on an exposed portion of the screw shaft or preferably on an axial extension thereof. For example, a suitable rotary valve connection is conventionally employed in the art for circulating cooling fluid to the internal bore of an extruder screw.

The temperature of the internally heated zone is capable of being varied along the length of the extruder screw but the minimum temperature to which this zone is heated is suitably in the range Tv to (T plus 50)°C preferably in the range (T_v+5) to T°C wherein T°C is the desired melt temperature at the extruder head and T_v is the Vicat softening temperature of the thermoplastic polymer measured in accordance with BS 2782: Part 1: Method 120A: 1976.

The internal heating in the process of the present invention must be such as to provide a net heat input into the thermoplastic polymeric material in the internal heating zone. In the case that the internal heating is provided by an internal electric resistance heater this condition will inevitably be satisfied. On the other hand, when the internal heating is provided by circulation of a heated fluid, the temperature of the fluid in the internal heating zone must be sufficiently high to maintain a flow of heat into the thermplastics rather than in the reverse direction. This condition can be established, for example, by ensuring that the fluid input to the internal heating zone is at a higher temperature than the fluid output therefrom.

In a preferred embodiment of the invention, provision is included for independent internal cooling of one or more parts of the screw before and/or after the internal heater, by any suitable means, for example by circulating a relatively cool fluid (e.g. oil or water) through said one or more parts. Such cooling can, for example, be applied within the metering zone of the extruder screw to avoid undue heating arising from mechanical working of the polymer in this zone. If desired, cooling can be applied to the solids conveying zone to avoid premature melting of the polymer on the screw.

Examples of thermoplastic polymeric materials suitable for use in the process of the present invention are high, medium and low density polethylene, linear low density polyethylene, polyproylene, polystyrene, hgh-impact polystyrene, acrylonitrile-butadiene-styrene coplymer (ABS), polyvinyl chloride, polyamide, methacrylate polymer, polycarbonate and polysulphone. Preferred materials are polystyrene, high-impact polystyrene and linear low density polyethylene.

Figure 1 of the accompanying drawings illustrates diagrammatically in cross-section the feed zone and part of the melting zone of an extruder screw fitted with internal heating in accordance with the present invention.

In Fig. 1, the rear unflighted end 2 of an extruder screw 1 having an internal bore 3 is internally threaded 4 to receive the male thread on an extension tube 5. The extruder screw has a conventional helical flight 6 the feed zone of which is indicated by reference letter A. The internal bore 3 contains an electric heater 7 situated in the melting zone which commences at the portion of the screw flight indicated by reference letter B. Electricity is delivered to the heater 7 via contacts (not shown) bearing on slip rings 8 connected to insulated conductors 9 which are housed in a steel tube 10. The temperature of the internal heater may be monitored, for example, by positioning a thermocouple adjacent to the heater and measuring the output

from the thermocouple via insulated conductors (not shown) housed within steel tube 10 and connected to a further pair of slip rings (not shown) similar to slip rings 8. The output from the thermocouple can be used to provide control over the temperature of the internal heater.

The extrusion process of the present invention can be applied, for example to the extrusion of pipe or to the production of film by extrusion-film blowing or slot casting. The process provides improved control of the extrusion and generally provides improved pressure generation in the melt, improved conveying and solid bed compaction in the early melting zone and increased melting rate. These features can lead to improved specific output (as measured for example in kg polymer/hr/screw rpm), to increased maximum output (kg per hour) and/or to reduced motor power requirements. The present invention is particularly beneficial for (i) achieving higher outputs from extruders which are already motor power limited and (ii) optimisation of extruders which are required to run on different materials from time to time.

The invention is further described with reference to the following Examples and Comparative Tests.

Examples and Comparative Tests

A 6.35 cm diameter single-screw extruder with two alternative helical flighted screws of differing design and a 6 cm diameter single-screw extruder were employed in the extrusion of several thermoplastic materials.

The screw designs and the thermoplastic materials employed in the extrusion are described below.

Extruder and Screw Designs These were as follows:

		Plaston Screw A	Plaston Screw B	Demag
Screw diameter	(mm)	63.5	63.5	60
L/D		24	24	27
Feed length	(diameters)	6	5	6
Transition length	(")	4	5	5.5
Metering length 1	(")	14	14	8.5
Mixer length	(")	-	-	2.5
Metering length 2	(")	-	-	4.5
Feed depth	(mm)	7	11	11
Metering depth 1	(mm)	2	4	5.5
Metering depth 2	(mm)	-	-	7.0
Pitch	(diameters)	1	1	1
Screw heater position	(diameters)	4½-10	4½-10	4-10

The extruder screws both had a 15.9 mm bore and contained a 35.6 cm 1800 watt electric cartridge heater, extending axially in the melting zone. In screw A the heater spanned the distance between the fourth and ninth diameters and in screw B the heater spanned the distance between the fifth and tenth diameters, measured from the feed end.

Materials The 6 materials used in the Tests and Examples were:

I	HS crystal polystyrene of 3.2 MI		
II	CP91 high-impact polystyrene of 4.2 MI		
III	Rigidex 002-55 high density polyethylene of 0.2 MI		Ex
IV	LL103AA linear low density polyethylene of 1 MI		BPCL
V	LL101AA linear low density polyethylene <u>powder</u> of 0.9 MI		Ltd.
VI	LL101AA linear low density polyethylene <u>pellet</u> 0.9 MI		

The melt indices were measured in accordance with BS 2782 Part 7 method 720A:1979. For materials I and II Test condition 8 was employed and for materials III, IV, V and VI Test condition 4.

During these runs recycled regrinds from earlier runs were found to give similar results to the virgin materials.

Extrusion Trials and Results

Several individual processing runs were completed and logged. All the trials were conducted at set barrel temperatures in the range 175°C–205°C. The results, summarised in Tables 1 and 2, showed improved specific output (up to +19%) and pressure generation with use of the internal heater and/or reduced amps.

TABLE 1
RESULTS WITH PLASTON 24:1 2.5" EXTRUDER

Example or Test	Screw Design	Screw Internal Heating	Screw rpm	Thermo-plastic Material	Motor Current amps	Pressure at 12D(1) psi	Extrudate output kg/hr	Output Increase %	Melt Temperature °C(2)
Example 1	A	Yes	41	III	33.0	4307	20.16	2.3	219.6
Test 1	"	No	"	"	33.5	3623	19.70		219.1
Test 2	A	No	70	III	34.5	3983	31.74		225.9
Example 2	"	Yes	"	"	34.0	5110	32.25	1.6	224.3
Test 3	A	No	68	I	30	2477	38.95		208.8
Example 3	"	Yes	"	"	28.5	3734	41.28	6.0	209.2
Test 4	A	No	60	IV	41.0	6532	28.5		220.0
Example 4	"	Yes	"	"	40.0	7501	29.0	1.8	219.9
Test 5	A	No	66	V	43.0	6996	30.87		222.2
Example 5	"	Yes	"	"	41.8	7580	31.56	2.2	222.9
Test 6	A	No	70	II	27.0	1462	37.13		204.7
Example 6	"	Yes	"	"	25.7	2692	39.26	5.7	204.9
Test 7	B	No	70	II	27.5	41	71.5		199.8
Example 7	"	Yes	"	"	27.6	1390	80.3	12.3	200.1
Test 8	B	No	70	I	26.0	37	75.5		199.8
Example 8	"	Yes	"	"	27.5	1127	90.0	19.2	200.7
Test 9	B	No	70	V	43.0	2766	61.9		209.0
Example 9	"	Yes	"	"	41.0	3924	64.5	4.2	210.3

1) Pressure measured 12 diameters from start of feed section.
2) Melt temperature measured by thermocouple positioned close to the output end of the screw.

TABLE 2

RESULTS WITH DEMAG 27:1 60 mm FILM EXTRUDER

Ex. No. Test No.	Screw Heating	Screw Speed rpm	Material	Motor Current amps	Output kg/hr	Output Increase %	Melt Temp. in adaptor °C
Test 10	No	30	VI	39	27.4		204
Ex. 10	Yes	"	"	37.5	30.35	10.8	200
Test 11	No	50	"	46.5	48.0		210
Ex. 11	Yes	"	"	44.0	49.56	3.3	209
Test 12	No	80	"	54	73.68		224
Ex. 12	Yes	"	"	53.5	80.3	9.0	224
Test 13	No	100	"	60	92.6		234
Ex. 13	Yes	"	"	58	95.8	3.5	234

From the Tables, it can be seen that the use of the internal screw heater increases the extrudate output by up to 19% and frequently leads to a reduction in motor amps. The thermoplastic melt pressure is increased (as measured at 12 diameters along the screw) by use of the internal heater and the melt temperature close to the output end of the screw is only slightly higher than is obtained in the absence of the internal heating.

CLAIMS

1. A single-screw extruder for extruding thermoplastic polymeric material characterised in that means are provided for internally heating a zone of the extruder screw comprising at least a portion of the melting zone of the screw, the axial length of the internally heated zone being from 2% to 90%, preferably from 2 to 50% of the flighted length of the screw.

2. A single-screw extruder according to claim 1 wherein the screw is fitted with conventional barrel heating in addition to the internal heating in the screw.

3. A single-screw extruder according to claim 1 or 2 wherein the internal heating means is situated with the core of the screw.

4. A single-screw extruder according to claim 3 wherein the internal heating means situated within the core of the screw extends along at least 2 length % of the total length of the melting zone.

5. A single-screw extruder according to any one of the preceding claims wherein the internal heating means extends from a point within the melting zone just beyond the commencement of melting, to a point within said melting zone at which melting is no more than 75% complete.

6. A single-screw extruder according to any one of the preceding claims wherein the internal heating means comprises electric resistance heating, electric induction heating or heated fluids.

7. A single-screw extruder according to any one of the preceding claims wherein the temperature of the internally heated zone is capable of being varied along the length of the extruder screw in the range Tv to (T plus 50)°C wherein T°C is the desired melt temperature at the extruder head and T_v is the Vicat softening temperature of the thermoplastic polymer measured in accordance with BS 2782: Part 1: Method 120A: 1976.

8. A process for extruding thermoplastic polymeric material using a single-screw extruder characterised in that a zone of the extruder screw comprising at least a portion of the screw where the thermoplastic polymeric material undergoes melting is internally heated, the axial length of the internally heated zone being from 2% to 90%, preferably from 2 to 50% of the flighted length of the screw.

9. A process according to claim 8 wherein the thermoplastic material to be extruded is selected from high, medium and low density polyethylene; linear low density polyethylene; polypropylene; polystyrene; high-impact polystyrene; acrylonitrile-butadiene-styrene copolymer (ABS); polyvinyl chloride; polyamide; methacrylate polymer; polycarbonate; and polysulphone.

10. An apparatus according to claim 1 as hereinbefore described with reference to the accompanying drawing.

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